BACTERIAL SOFT ROT IN BELL PEPPERS

Cause and Commercial Control

Marketing Research Report No. 738

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

CAUTION

If pesticides are handled or applied improperly, they may be injurious to humans, domestic animals, desirable plants, and pollinating insects, fish, or other wildlife, and may contaminate water supplies. Use pesticides only when needed and handle them with care. Follow the directions and heed all precautions on the container label.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE

Washington, D.C. Issued March, 1966

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402 - Price 5 cents

BACTERIAL SOFT ROT IN BELL PEPPERS

Cause and Commercial Control

By Howard B. Johnson

Market Quality Research Division, Agricultural Research Service, U.S. Department of Agriculture

SUMMARY

Preliminary tests showed a correlation between high moisture content in pod stems of bell peppers and increased susceptibility to bacterial soft rot infection in the packing shed.

Natural (abscission) stem breaks showed inherent resistance to soft rot infection in peppers collected in field and packing shed.

Samples of peppers were collected in the field and packing shed to pinpoint the sources of bacterial soft rot infection. The greatest increase, more than fourfold, occurred in samples collected after the brush-waxer unit. This sharp increase in infection suggests the removal of waxers with brushes from the packing lines.

Indications are that the soft rot infection that occurs at the brush-waxer can be substantially reduced by applications, several times daily, of 600 parts per million (p.p.m.) chlorine spray. A delay of 30 minutes or more between the completion of each spraying and the resumption of packing is necessary for satisfactory control. In addition, spraying the entire packing line with chlorine at least once daily is suggested.

Hot water reduced decay in long-stemmed bell peppers that had been inoculated with bacterial soft rot 6 hours before treatment. The effectiveness of the hot water treatment (128° F. for 1½ minutes) was increased slightly by the addition of 150 to 300 p.p.m. chlorine. A safe operating range appears to be 126° to 128° for 1½ minutes.

The control obtained with hot water alone or combined with chlorine was completely nullified by subsequent hydrocooling, even when chlorine was added to the hydrocooling water. The moisture added by hydrocooling was apparently responsible for the increased infection in inoculated peppers.

INTRODUCTION

Bacterial soft rot (*Erwinia carotovora* (L. R. Jones) Holland, and other bacteria) is the most destructive postharvest decay of bell peppers. The bacteria are common in most soils and normally invade the pod through wounds. Broken stems, resulting from harvesting, provide an ideal entry point for infection after contact either with contaminated soil or with picking and packing equipment. The stem and calyx lobe tissues are affected first, followed closely by the pod. The entire pod can be reduced to a soupy mass within 3 to 6 days under humid conditions and optimum temperatures (75° to 85° F.).

In recent years losses up to 50 percent have been reported in bell pepper shipments from the Lower Rio Grande Valley in Texas. Losses of such magnitude are usually associated with unfavorable weather and cultural conditions before harvest; that is, heavy rains after fertilization and normal irrigation. However, considerable losses have been experienced under conditions not usually considered as conducive to soft rot infection. The results of decay control tests, using inoculated peppers, suggest that susceptibility to soft rot infection may vary between seasons and also between specific fields of peppers in the same season.

Refrigeration during transit is necessary to retard decay and color change in green peppers. Hydrocooling and chemical washes during the packing operation are sometimes used to supplement transit refrigeration. Hydrocooling effectively removes field heat from bell peppers and by so

795-478—66

doing affords transitory protection against the development of soft rot. However, the moisture added by the treatment increases the chance of soft rot before the product is consumed. Peppers with open stylar ends sometimes fill with water during hydrocooling.

The few chemicals that have been approved for postharvest use on peppers are generally effective in preventing a buildup of decay-producing organisms on the surface of the pepper and in the treatment bath. Few, if any, will control an incipient infection of bacterial soft rot.

A number of workers have reported that hot water or heat treatments effectively reduced decay in fruits and vegetables (*1* through *14*).[1] The success reported by Smith (*11*) in reducing incipient infections of two decay-producing fungi on inoculated peaches led to the inclusion of such treatments in tests with bell peppers. The potential value of hot water treatments for the reduction of bacterial soft rot in peppers has since been reported (*6*).

Studies made in the field and packing shed to pinpoint the locations at which soft rot infections occur and the results of controlled laboratory tests are discussed in this report. The studies were conducted in the Lower Rio Grande Valley of Texas during three shipping seasons, fall of 1963 and spring and fall of 1964.

[1] Italic numbers in parentheses refer to Literature Cited, p. 6.

GENERAL METHODS

Samples of peppers were collected at three standard points in commercial packing sheds. These points were (1) field truck unloading belt, (2) after the waxer unit, and (3) after the waxer unit and hydrocooler (if used).

Peppers collected in fields and packing sheds were carried in polyethylene film bags from points of collection to the laboratory. Here they were put in cartons and held 6 days at 70° F. in high relative humidity before final scoring of infections.

PROCEDURE AND RESULTS

Effect of Fertilization and Tissue Moisture on Infection and Control

Long-stemmed pods were collected in late season from four fields that had received different fertilization, ranging from nitrogen alone to a completely balanced fertilizer. The peppers were marked and randomized into two samples of 20 and 25 pods from each field.

The stems in the first group were slightly cut before being snapped off, resulting in uniform semi-jagged stem breaks. These peppers were passed through a contaminated waxer and examined for infections after the 6-day holding period.

The second group of pods were inoculated with soft rot and after 6 hours treated with hot water (128° F. for 1½ minutes); they were examined for infection after the 6-day holding period.

Moisture determinations were made on samples of the discarded stem tips from the first group of peppers. The pod stems showed a difference of 1.74 percent between the highest and lowest dry weights. The field that produced the peppers with the highest pod stem moisture had received more than three times as much nitrogen as the field with the lowest pod stem moisture. Peppers from these two fields differed in their susceptibility to infection from waxing in a contaminated unit. Pods with the highest stem moisture content developed 75 percent infection compared with 40 percent infection in those with the lowest stem moisture. Also, peppers from the same two fields showed a difference in the degree of control obtained with hot water after inoculation with soft rot as follows:

Percentage of peppers decayed

Pod stems	*Check lot*	*Hot water lot*	*Reduction in decay by hot water* [1]
Highest moisture	96	56	42
Lowest moisture	96	28	71

[1] Compared with percentage of infections in inoculated check lot of peppers. x=percent of peppers infected in check lot; y=percent of peppers infected in hot water treated lot; $\frac{x-y}{x}\times 100$=percent control by hot water treatment.

Leaf samples collected earlier in the season from the four fields were analyzed for total and soluble nitrogen.[2] The analyses for leaf nitrogen revealed no significant differences between samples from the four fields.

[2] Analyzed by personnel of the Soil and Water Conservation Research Division, U.S. Department of Agriculture, Weslaco, Texas.

Effect of Type of Stem Break on Infection

Peppers with three types of stem breaks, namely, clipped, jagged, and natural resulting from formation of normal abscission layer, were collected from a fifth field. Half the peppers of each of the 40-pod samples of each type of stem break were run through a contaminated waxer and the rest were left unwaxed. These peppers were collected in film bags in the field and held thus, instead of in the customary carton, for 6 days at 70° F.

The natural (abscission) type of stem break on unwaxed and waxed peppers showed an inherent resistance both to field and to waxer-induced infection of bacterial soft rot. A comparison of the relative susceptibility of the three types of stem breaks follows:

Percentage of peppers infected

Type of stem break	*Unwaxed peppers*	*Waxed peppers*
Clipped	10	80
Jagged	25	90
Natural	0	25

Also, peppers with jagged and natural stem breaks were collected at three points in two packing sheds (see "General Methods"). A total of 6 replicates of 10 pods each of each type of stem break was collected at the field truck unloading belt and after the waxer unit, and 4 replicates were collected after the waxer and hydrocooler. These samples were held for 6 days at 70° F. The pods with natural stem breaks exhibited the same inherent resistance to infection as those collected in the field. The relative susceptibility of jagged and natural stem breaks to infection in the packing shed follows:

Percentage of pods infected

Type of stem break	*Pods collected at truck unloading belt*	*Pods collected at waxer*	*Pods collected at waxer-hydrocooler*
Jagged	17	77	88
Natural	5	23	38

Sources of Infection in Packing Shed

Samples of peppers were collected in the packing sheds, at the three collection points described under "General Methods," to pinpoint the sources of soft rot infection. The results are given in table 1.

With the exception of the one sample from shed F, the samples collected after the brush-waxer showed sharp increases in percentage of pods infected. Contamination of the brush-waxer with soft rot inoculum was largely responsible rather than the actual waxing operation. Although the percentage of infected pods was increased slightly by hydrocooling, the primary source of inoculum was the waxer.

TABLE 1.—*Number of peppers collected from three locations in packing lines and percentage infected with bacterial soft rot after being held 6 days at 70° F.*

Shed	No. of samples	Peppers collected at truck unloading belt		Peppers collected after waxer		Peppers collected after waxer-hydrocooler [1]	
		Total	With soft rot	Total	With soft rot	Total	With soft rot
		Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
A	1	19	10	19	73	0	0
B [2]	3	59	5	0	0	60	52
C	2	93	10	97	41	0	0
D [2]	2	40	7	40	22	0	0
E	1	19	0	19	63	0	0
F [2]	1	21	0	22	0	0	0
G [2]	10	199	9	180	49	178	61
H	5	183	21	192	55	0	0
I [2]	3	60	0	0	0	58	38
J	1	20	5	19	89	0	0
Total	29	713	11	588	49	296	54

[1] Hydrocooled 5 to 7 minutes in 36° to 40° F. water.
[2] A chlorine concentration of 200 to 300 p.p.m. was used in the packing line as a decay preventive.

All packing sheds in the Lower Rio Grande Valley are equipped to wax bell peppers. Some also wash or hydrocool them. The waxer unit in the packing line is a potential source of soft rot infection to all peppers passing through it because of the accumulative inoculum on the brushes. In view of the more than fourfold increase in infection that occurred in samples collected after the brush-waxer, it is suggested that either this piece of equipment be removed from packing lines or a good sanitation program be applied to it.

Chlorine was used as a decay preventive treatment in 5 of the 10 packing sheds at the time of the survey (table 1). In most sheds the material is metered automatically into the treatment solution to maintain a 200 to 300 p.p.m. chlorine concentration. The solution is applied either as a spray in a separate unit or in the hydrocooler.

Cleanup Spray for Packing Line

A collection of 100 pods from each of two fields was divided into three samples, and the pods were marked. Two samples from each field were passed through commercial waxer units; one sample was passed through a sanitized waxer and one through a contaminated waxer. The third set of samples was left unwaxed. All samples were held 6 days at 70° F.

Peppers that were waxed experimentally in a commercial waxer that had been sprayed with an antibiotic developed no soft rot infections during subsequent holding. Comparable peppers that were left unwaxed likewise developed no infections, but those waxed in an untreated unit averaged 12 percent decay. Antibiotics are not cleared for this use, but the experiment did clearly indicate that contamination of the waxing unit was responsible for soft rot infections in the waxed peppers.

Cleanup of the waxer unit by steam is precluded by the industrywide use of synthetic bristles in the brush assembly. Hence, spray tests for this purpose were run using chlorine.

A total of four samples of jagged-stemmed peppers were collected, three samples from one packing shed and one from a second shed. Half the peppers of each 200-pod sample were run through a contaminated waxer before it was sprayed, and the second lot afterward. The spray used consisted of 1 part laundry bleach and 19 parts water, or approximately 600 p.p.m. chlorine. It was prepared fresh as needed and applied as a wetting spray to the brush assembly in the waxer and on the roller conveyors immediately before and after the waxer. The peppers used in these tests were collected and held as described under "General Methods" before being examined for infections.

A 30-minute delay between completion of spraying and resumption of the packing operation occurred in two of the tests, whereas in the other two there was no delay. The importance of at least a 30-minute delay is shown in the following tabulation by the percentage of infected pods in the samples run through the sprayed waxer and the degree of control resulting from the spray:

Percentage of peppers decayed

Elapsed time	*Unsprayed waxer*	*Sprayed waxer*	*Reduction in decay by spraying* [1]
30 minutes	66	23	65
No delay	85	69	19

[1] Compared with percentage of infections in peppers passed through the unsprayed waxer. x=percent of peppers infected in unsprayed lot; y=percent of peppers infected in lot passed through sprayed waxer; $\frac{x-y}{x}\times 100$=percent control by spray.

The difficulty in controlling soft rot by sanitizing the brush-waxer with chlorine spray is shown by the control figures. A single thorough application of strong spray followed immediately by running peppers through the unit reduced infection only 19 percent. A similar spray application followed by a 30-minute delay in packing peppers reduced infection 65 percent. However, regular sprayings several times daily could be expected to gradually reduce the percentage of infection that occurs at the waxer unit. A good sanitation program should include spraying the entire packing line at least once daily, preferably at the end of the workday.

Effect of Treatments on Soft Rot Infection in Inoculated Peppers (Laboratory Tests)

Long-stemmed peppers were selected at commercial sheds soon after delivery from the fields and before washing or waxing. The stems were recut at the laboratory shortly before the peppers were artificially inoculated.

The peppers were arranged with stems up in water-soaked wooden lug boxes, and each stem was flooded with several drops of inoculum. The inoculum used was a fresh suspension of stem tissues from two peppers infected with bacterial soft rot and was made up to 100 milliliters with water

plus one drop of Triton X–100 [3] (alkylated aryl polyether alcohol). The individual boxes containing inoculated peppers were enclosed loosely in polyethylene film and held at 70° F. in high relative humidity for 5 to 7 hours before the peppers were treated for decay control.

In a 4-replicate test, three standard decay control treatments were used: Chlorine solution (300 p.p.m.) at 75° F. for ½ minute; hot water, 128° for 1½ minutes; and a combination of hot water plus chlorine. The chlorine solution was prepared fresh as needed from a commonly used laundry bleach (sodium hypochlorite 5.25 percent by weight) in proportion 1 part bleach to 38 parts water. The resulting solution contained approximately 300 p.p.m. chlorine with a pH reading of 8.8.

After treatment the peppers were allowed to drain for several minutes, then placed in cartons at 70° F. and held 6 days before infections were scored.

In a 3-replicate test, previously treated inoculated peppers were hydrocooled for 6 minutes in 40° F. water only or with chlorine (300 p.p.m.) added. After hydrocooling the peppers were held 6 days at 70°.

The results obtained with hot water and chlorine treatments in reduction of soft rot infection in inoculated pods and the effect of subsequent hydrocooling on control are shown in table 2. The hot water treatment (128° F. for 1½ minutes) effectively controlled infection in both the 4- and 3-replicate tests. The addition of chlorine (300 p.p.m.) to hot water improved control slightly over that obtained with hot water alone. Preliminary tests indicated 150 p.p.m. chlorine was as effective as 300 p.p.m. when used in hot water. However, chlorine treatments at either concentration in 75° water for ½ minute were not effective. The good control obtained either with hot water alone or combined with chlorine was completely nullified by subsequent hydrocooling with water alone or with chlorine added. The moisture added by the hydrocooling was apparently responsible for the increased infection.

Pod Injury Resulting From Treatments

The hot water treatment used is close to the threshold of injury in bell peppers. Pod injury can be expected if either the temperature of the water or exposure to it is increased above the recommended range of 126° to 128° F. for 1½ minutes. Immature, poorly formed pods were sometimes injured by the treatment. The injury was evidenced by shallow surface pits similar to low temperature pitting.

No pod injury or color fading resulted from the chlorine treatments.

Other decay control treatments, not previously mentioned, were tried and discontinued because they either failed to reduce infection in inoculated pods or caused injury. These treatments included hot air, sorbic acid, table salt, and electric infrared radiation.

[3] Trade names are used in this report solely to provide specific information. Mention of a trade name does not constitute endorsement of the products used nor imply discrimination against other products.

Table 2.—*Peppers infected with bacterial soft rot after being treated with hot water and chlorine, hydrocooled, and held 6 days at 70° F. and reduction in infections compared with infections of untreated peppers*

Test and treatment	Peppers	After 6 days at 70° F.: Infections	After 6 days at 70° F.: Control [1]
4-replicate test	*Number*	*Percent*	*Percent*
75° F. water, ½ minute:			
Water only [2]	68	84	-----
Chlorine (300 p.p.m.)	68	53	37
128° F., 1½ minutes:			
Water only	68	21	75
Chlorine (300 p.p.m.)	68	16	81
3-replicate test			
75° F., ½ minute:			
Water only [3]	52	85	-----
128° F., 1½ minutes:			
Water only	52	19	78
Chlorine (300 p.p.m.)	52	15	82
128° F., 1½ minutes, plus hydrocooling:			
Water only	56	100	0
Water only; chlorine (300 p.p.m.) in hydrocooler	55	80	6
Chlorine (300 p.p.m.) in treating tank only	56	96	0
Chlorine (300 p.p.m.) in treating tank and hydrocooler	56	86	0

[1] Compared with percentage of infections in inoculated check lot (75° F. water treatment). x=percent of peppers infected in check lot; y=percent of peppers infected in treated lot; $\frac{x-y}{x} \times 100 =$ percent control.

[2] For calculating percent control in 4-replicate test lots.

[3] For calculating percent control in 3-replicate test lots.

Pod Temperatures Resulting From Hot Water

Pod temperatures during the hot water treatment (128° F. for 1½ minutes) were taken with small-gage wire thermocouples attached to a potentiometer. In a 3-replicate test, temperatures were obtained in long-stemmed peppers in three positions: Center of stem tip, pod wall opposite partition, and air inside pod.

The pod temperatures at the start and end of the hot water treatment follow:

Temperatures before and after treatment

	Start ° *F.*	*End* ° *F.*
Stem tip	90. 6	125. 7
Pod wall (¼" depth)	89. 8	108. 2
Inside pod air	90. 6	110. 3

Tissue temperatures resulting from the hot water treatment showed its effectiveness with long-stemmed pods. The temperature at the stem tip reached 125.7° F. or nearly 2 degrees above the thermal death point of the organisms involved.

LITERATURE CITED

(1) AKAMINE, ERNEST K.
1953. CONTROL OF POSTHARVEST STORAGE DECAY OF FRUITS OF PAPAYAS (CARICA PAPAYA L) WITH SPECIAL REFERENCE TO THE EFFECT OF HOT WATER. Amer. Soc. Hort. Sci. Proc. 61: 270–274.

(2) ———
1960. TEMPERATURE EFFECTS IN FRESH PAPAYAS PROCESSED FOR SHIPMENT. Hawaii Agr. Expt. Sta. Bul. 122, 14 pp.

(3) ARISUMI, T.
1956. TEST SHIPMENTS OF PAPAYAS WITH SPECIAL REFERENCE TO STORAGE DECAY CONTROL. Hawaii Agr. Expt. Sta. Tech. Bul. 29, 16 pp.

(4) BURCHILL, R. T.
1964. HOT WATER AS POSSIBLE POST-HARVEST CONTROL OF GLOEOSPORIUM ROTS OF STORED APPLES. East Malling (Eng.) Res. Sta. Ann. Rpt. 106–107.

(5) FAWCETT, H. S.
1922. PACKING HOUSE CONTROL OF BROWN ROT. Calif. Citrog. 7(7): 232, 254.

(6) JOHNSON, HOWARD B.
1964. EFFECT OF HOT WATER TREATMENTS AND HYDROCOOLING ON POSTHARVEST BACTERIAL SOFT ROT IN BELL PEPPERS. U.S. Dept. Agr. AMS–517, 6 pp.

(7) KLOTZ, L. J., and DEWOLFE, T. A.
1961. LIMITATIONS OF THE HOT WATER IMMERSION TREATMENT FOR THE CONTROL OF PHYTOPHTHORA BROWN ROT OF LEMONS. U.S. Dept. Agr. Plant. Dis. Rptr. 45: 264–267.

(8) KUSHMAN, L. J., and COOLEY, J. S.
1949. EFFECT OF HEAT ON BLACK ROT AND KEEPING QUALITY OF SWEET POTATOES. U.S. Dept. Agr. Jour. Agr. Res. 78: 183–190.

(9) PENNOCK, W., and MALDONALDO, G.
1962. HOT WATER TREATMENTS OF MANGO FRUITS TO REDUCE ANTHRACNOSE DECAY. Jour. Agr. Res. Puerto Rico 46(4): 272–283.

(10) ROSBERG, DAVID W., and JOHNSON, H. B.
1959. ARTIFICIAL CURING OF TEXAS ONIONS. Tex. Agr. Expt. Sta. MP–395, 7 pp.

(11) SMITH, W. L., JR.
1962. REDUCTION OF POSTHARVEST BROWN ROT AND RHIZOPUS DECAY OF EASTERN PEACHES WITH HOT WATER. U.S. Dept. Agr. Plant Dis. Rptr. 46(12): 861–865.

(12) ——— BASSETT, R. D., PARSONS, C. S., and ANDERSON, R. E.
1964. REDUCTION OF POSTHARVEST DECAY OF PEACHES AND NECTARINES WITH HEAT TREATMENTS. U.S. Dept. Agr. Mktg. Res. Rpt. 643, 23 pp., illus.

(13) SMOOT, JOHN J., and SEGALL, R. H.
1963. HOT WATER AS A POSTHARVEST CONTROL OF MANGO ANTHRACNOSE. U.S. Dept. Agr. Plant Dis. Rptr. 47(8): 739–742.

(14) TINDALE, G. B., JENKINS, P. T., and PEGGIE, I. D.
1958. BROWN ROT IN CANNING PEACHES. Victoria Jour. Agr. 56: 107–111.

U.S. GOVERNMENT PRINTING OFFICE: 1966